

# Dependency Directed Reconsideration

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## Introduction and Background

If a knowledge representation and reasoning (KRR) system gains *new* information that, in hindsight, might have altered the outcome of an earlier belief change decision, the earlier decision should be re-examined. We call this operation *reconsideration* (Johnson & Shapiro, 2004), and the result is an optimal belief base regardless of the order of previous belief change operations. This is similar to how discussion in a jury room can help jurors to optimize their interpretation of the evidence in a trial, regardless of the order in which that evidence was presented.

To simplify our example, we assume a global decision function is used in the belief change operations, and it will favor retaining the most preferred beliefs as determined by a preference ordering ( $\succ$ ) that is irreflexive, anti-symmetric and transitive. Any base can be represented as a sequence of beliefs in order of decending preference:  $B = p_1, p_2, \dots, p_n$ , where  $p_i$  is preferred over  $p_{i+1}$  ( $p_i \succ p_{i+1}$ ).

Reconsideration requires maintaining a set of all beliefs that have ever been in the belief base at any time (effectively, the union of all past and current bases),  $B^\cup$ . The base produced by reconsideration is defined as  $B^\cup!$  where  $!$  is a consolidation operation (which eliminates *any and all* inconsistencies) (Hansson, 1999).

A base,  $B = p_1, p_2, \dots, p_n$ , is optimal if it has the most credible beliefs possible without raising an inconsistency: i.e. it is consistent and there is no  $B' = q_1, q_2, \dots, q_m$  s.t.  $B' \subseteq B^\cup$ ,  $B'$  is consistent, and either  $B \subset B'$  or  $\exists q_i$  s.t.  $q_i \succ p_i$  and  $p_1, p_2, \dots, p_{i-1} = q_1, q_2, \dots, q_{i-1}$ .

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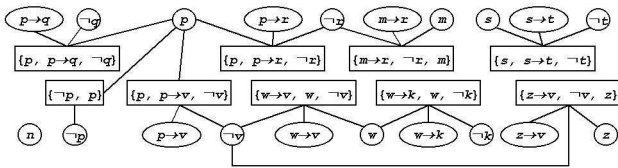


Figure 1: A graph showing the elements of  $B^\cup$  (circles/ovals) of a KS connected to their minimally inconsistent sets (rectangles), where  $B^\cup = \neg p, p, p \rightarrow q, p \rightarrow r, m \rightarrow r, s \rightarrow t, w \rightarrow v, w \rightarrow k, p \rightarrow v, z \rightarrow v, n, \neg q, \neg r, w, s, \neg v, m, z, \neg t, \neg k$ .

Consider the base beliefs in Figure 1 *prior* to the addition of  $\neg p$ . The optimal base would be  $B1 = \{p, p \rightarrow q, p \rightarrow$

$r, m \rightarrow r, s \rightarrow t, w \rightarrow v, w \rightarrow k, p \rightarrow v, z \rightarrow v, n, w, s, m, z\}$ , with  $\neg q, \neg r, \neg v, \neg t$ , and  $\neg k$  removed. Adding  $\neg p$  to  $B1$  now forces the retraction of  $p$ . MOST SYSTEMS STOP HERE.

A literal implementation of reconsideration would examine *all* removed beliefs. Dependency Directed Reconsideration (DDR), however, only reconsiders removed beliefs whose inconsistent sets have had *changes* in the belief status of their elements. It reconsiders these beliefs in decending order of preference, updating the base as it goes and maintaining a global priority queue of beliefs yet to be reconsidered. A removed belief can return as long as any inconsistency it raises is resolved through the removal of a *less preferred* belief.

As with a literal implementation of reconsideration, DDR first produces the following changes: (1)  $\neg q$  returns to the base, and (2)  $\neg r$  returns to the base with the simultaneous removal of  $m$ , because  $\neg r \succ m$  (consistency maintenance). However, once DDR determines that  $\neg v$  cannot return to the base (due to its being the culprit for the inconsistent set  $\{w \rightarrow v, w, \neg v\}$ ), it would would prune off the examination of the inconsistent sets containing  $\neg k$  and  $z$ . The inconsistent set containing  $s$  would also be ignored by DDR — it is not connected to  $p$  in any way. This latter case is representative of the possibly thousands of unrelated inconsistent sets for a typical belief base which *would* be checked during a literal  $B^\cup!$  operation of reconsideration, but are ignored by DDR.

DDR is an anytime algorithm: if starting with a consistent base, a consistent base is always available, and the optimality of that base improves with increased execution time. Additionally, an interrupted DDR can be continued at a later time as long as the priority queue has been maintained. If run to completion, the base will be optimal (as with reconsideration) — thus, the KRR system can make the most reliable inferences, and belief change operation order will have no effect.

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